Mobile inquiry-based learning for sustainability education in secondary schools

Effects on knowledge and motivation

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Abstract—**This paper reports about experiences and lessons learned from a recently conducted pilot study about sustainability education with mobile inquiry-based learning in a secondary school in the Netherlands. In the pilot study learners were involved in a mobile location-based game that was conducted in reserved time-slots over 5 weeks. Mobile devices of the school and of learners have been combined with a smart-energy meter network to support learning activities covering the full inquiry cycle. Analysis of data collected shows that the implementation was beneficial for learners with a low prior knowledge level and that future designs should take into account gender aspects in the design phase.**

Keywords: mobile learning; inquiry-based learning; environmental education; sustainability; implementation; knowledge building

I. Introduction

While we have earlier focused on environmental education with pervasive learning interventions at the workplace [1 – 2], we have recently conducted a pilot study in the school context. The project Sustainable inquiry based learning with ICT contributed to tackling the challenges of environmental education by designing, developing and implementing an instructional intervention in the form of a pilot study. The scientific inquiry approach focuses on relations between phenomena, on understanding cause-consequence relations, on discovering them in the surrounding environment, testing them in experiments, finding plausible explanations and digging further to find explanations to phenomena that are less evident [3].

Kwan & Miles [4] recommended identifying children's opinions and building on them in order to achieve success in environmental education. The goal of the project was to investigate the feasibility of implementing an inquiry learning scenario on energy consumption in the direct environment of the learner and integrating such a scenario in the school curriculum and to study the impact of an inquiry-based learning activity on knowledge domain development and on motivation.

In order to reach these aims an inquiry-based project was conducted in the science curriculum on the topic of energy consumption using a serious game and mobile learning principles. A series of instructional scripts (games) were designed to guide students in individual and collaborative inquiry activities on the topic of energy consumption. These scripts were delivered on personal mobile devices with the help of the ARLearn toolkit [5] as a series of games including game elements (such as challenges, fun elements and incentives). An energy sensor system enabled data collection on energy consumption of appliances within the school building. Data on use of mobile devices throughout the pilot were logged. Both prior to the pilot and after it, data were collected on learners' basic knowledge of energy consumption and on students' motivation.

In this paper we provide an overview of the pilot and report about the results and implications for future work. In the next sections we describe the methods and results of the pilot study and discuss them from the perspective on follow-up activities.

II. Method

A. Participants

To achieve the pilot goals, an inquiry-based learning activity in the form of a serious game on the topic of Energy and Sustainable Development was designed and integrated in the science curriculum of a secondary school (beginners' level, K-8) in the Netherlands. In this framework students (n=85) worked between 2 and 4 hours a week during a 5-week period on a project on energy consumption.

B. Materials and Instruments

The intervention consisted of 4 different components: Classroom teaching material for preparatory activities, a sensor-network to measure energy consumption of different devices in the school building, personal and school-owned mobile devices and last but not least game-scripts delivered via the ARLearn application. To collect data a basic knowledge test with 5 items on energy efficiency was combined with the 17-item intrinsic motivation scale based on Deci & Ryan [6].

C. Design & Procedure

At the start of the pilot and one week after its completion a paper and pencil questionnaire was administered (pre-post test design). 79 students filled in both questionnaires. Both pre- and post questionnaire included the five item knowledge test and the motivation scale. The 17-item prior knowledge test was issued only as pre-test.

The project was organized as a 6-phase inquiry cycle. Students started the project with a general introduction on the topic of energy consumption and an introduction of the tools (e.g. an app supporting data collection for their smartphones). They posed research questions in small teams, decided together how they would tackle the task, collected and analyzed data to answer the questions that they posed and presented the results to each other and the teachers in the form of posters during a poster walk.

During the project students acquired and applied knowledge of concepts such as electricity, energy consumption and energy efficiency, and trained research skills by conducting observations and measurements, doing calculations, analysing and interpreting information and communicating results. Thus, the project introduced its participants (K-8 level students) to a topic within the formal school curriculum contextualized by means of a familiar environmentand to scientific inquiry knowledge and methodology in general.

Throughout the pilot instructional support was provided by the teachers and by the researcher at regular instructional moments in class and through personal mobile devices (smartphones and tablets). Scripted instruction sent to their mobile devices included guidance of data collection in the orientation phase (at home and at school) and in the data collection phase (at school) by means of audio, video, photo and text formats.

Prior to the pilot a try-out was organized to let the students install an app on the personal mobile devices and get acquainted with some of the functionalities of this app. Informed consent request letters were distributed among the students for them and their parents. After the pilot a de-briefing was held through a short anonymous written student inventory and an interview with the teachers.

III. RESULTS

Knowledge and understanding of energy related concepts.

Performance on the 17-items test was used as an indication of prior knowledge level. Performance on the 5-items test was used to measure the effect of the intervention. This effect was compared both between en within groups with the help of non-parametric tests.

To examine knowledge improvement of students of different knowledge levels, the sample was divided into three approximately equal groups based on the distance of a standard deviation to the mean with below average (M<9); average (within 1 SD to the mean, 9<M<11) and above average (M>11) levels of prior knowledge. Normality tests were significant, therefore non-parametric tests were used. As Wilcoxon signed-rank test demonstrated, the low prior knowledge group performed significantly better on the post-test Z = - 2,484, p=.003, r = -.58. For the average and higher prior level knowledge groups changes in scores on the 5-items test were not significant.

Difference in prior knowledge between boys and girls was not significant. While knowledge improvement was demonstrated for the whole sample ($t(75) = 7.70$, $p = .00$, $r = .66$), separate paired samples t-tests yielded significant results only for girls ($t(29) = 2.644$, $p = .013$, $r = .44$).

Table 1 provides an overview of mean statistics on the knowledge tests for the whole sample and separate for groups by gender and by prior knowledge level.

Table 1. Knowledge level and changes in knowledge by gender and prior knowledge

Group	N	prior knowledge (17-items school test) *M (SD)*	5-items knowledge test prior to the experiment *M (SD)*	5-items knowledge test after the experiment *M (SD)*
M	43	9.40 (3.00)	3.44 (1.1)	3.62(1.19)
V	32	8,84(2,57)	3.08(.98)**	3.58(.90)**
M<9[1]	26	5.96 (1.61)***	2.80 (.98)***	3.60 (.1.19)***
9<M<11	30	10.00 (.75)	3.5 (1.13)	3.41(1.04)
M>11[1]	22	12.63 (0.89)	3.4 (.92)	3.8 (.98)
Total	75 72	9.2 (2.8)	2.349 (1.04)* 3,2	3.618 (1.08)*

* $t(75) = 7.70$, $p = .00$, $r = .66$
** $t(29) = 2.644$, $p = .013$, $r = .44$
*** z = - 2,484, p=.003, r = -.58

Motivation. First, a principal component analysis was conducted on pre-test and post-test 17-item scales to validate the motivation scale as recommended by Deci & Ryan [6]. Oblique rotation (direct oblimin) was used as it could be expected that the factors were related. According to the Keyser-Meyer-Olkin measure (resp., KMO = .820 and KMO=.800), the sampling was adequate for the analysis in both pre-test and post-test, KMO values for individual items were all above .7 for both scales, which is well above the acceptable limit of .5. Analysis of the pre-test scale yielded four components with eigenvalue above 1, combined they explain 64 % of the scale variance. The items suggest that components represent expected effort; interest, usefulness and willingness to do an inquiry. Analysis of the post-test scale yielded three components with an eigenvalue above 1 that explain 61% of the variance. These components could be clustered as effort the activity costs, interest/usefulness, and willingness to do (in retrospective). These components reasonably matched the scale divisions described in the literature and mirrored the contextual constraints of the pilot. Complete scales (mean scores) were used to produce scores representing motivation levels prior and after the pilot.

As can be seen at Table 2 and Figure 1, prior to the game girls were significantly more positive than boys. Significant difference in motivation levels between girls and boys seem to have faded away after the experience as repeated measures GLM showed statistically significant change in motivation level in time, while between groups effect did not reach significance ($F(1,56) = 2.625$, $p = .111$, $\eta p2 = .045$).

Table 2. Knowledge level and changes in knowledge by gender and prior knowledge

Group	N	Motivation scale in the pre-test *M (SD)*	Motivation scale in the post-test *M (SD)*
M	33	3,59 (,66)*	3,26 (,93)
V	25	4,12 (1,00)*	3,43 (1,03)
Total	58	3,82 (,86)* **	3,33 (,97)**

* $t(71) = -3.023$, $p = 004$, $r = .34$)
** $F(1,56) = 24.096$, $p = .000$, $\eta p2 = .301$

No differences in motivation levels by prior knowledge were found.

Usage and Implementation issues

The idea of using mobile phones for learning was met with enthusiastic reactions (personal observation). As indicated in an anonymous evaluation inventory, practically all students actually used some of the ARLearn game scripts. According to their response (measured holistically with a single yes/no item) they demonstrated appreciation of activities that included actions (taking pictures, recording) and were negative on games that focus on supportive information. These usage patterns could be confirmed with access data from the ARLearn system. Understandably, they were most critical of inadequate functioning of wifi network and lack of structure because of last-minute changes in the activity to compensate for malfunctioning facilities.

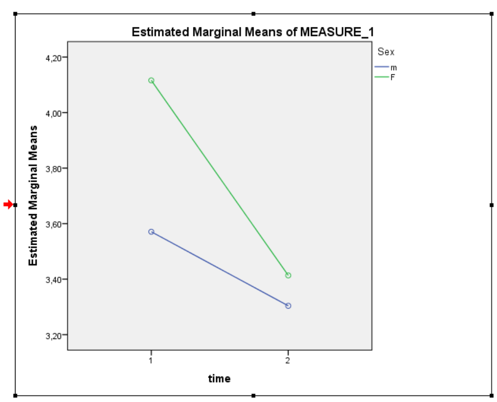

Figure 1. Decrease of motivation for female and male participants pre- and post measurement

IV. Discussion and Conclusions

According to the collected data, a knowledge gain for the whole sample was visible, albeit only significant for girls. As for motivation, we can state that an activity with a game component on the topic of energy consumption did not help to keep students interested in a topic they were not very enthusiastic about. Girls who seemed more interested were also most disillusioned. These findings indicate that taking gender differences into account when designing curriculum related game-components is worth considering. On the other hand, future studies need to confirm if this lack of motivation did not stem from implementation problems of this specific pilot study.

The pilot and in particular testing the scripts and scenarios of inquiry based learning with students and teachers helped to formulate requirements and use cases for developers of mobile and social media technologies based on end-users experiences. Thus, the pilot served as a baseline iteration in research of inquiry based learning with mobile technologies following the design-based research methodology. Several follow up activities are scheduled, including a new pilot run with the class of 2014-2015 on the same topic with revised and improved tools and materials. Results will be used to better understand these challenges and develop school-proof approaches for future technology-enhanced inquiry based learning scenarios.

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